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VLSI Solutions for Tiered Office Networks

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VLSI SOLUTIONS FOR TIERED OFFICE NETWORKS

CONTENTS

Introduction

Local area networks, or LANs, were developed as a response to the development of distributed intelligence. In the past decade the performance/price ratio of microprocessors has increased well over 1000 fold. It is these low cost microprocessors that have enabled computational capability formerly residing in a centralized computer to be placed on users' desks. However, the cost of computer peripherals (such as letter quality printers, Disk memories, and communication servers) has not dropped in a similar fashion (because of high electro-mechanical content). Also, there is an increasing need to share timely and accurate information among users in a business setting. LAN technology is the solution to these problems by allowing users to share the cost of peripherals and access common data bases.

As LANs begin to proliferate, it is becoming clear that no single network type can cost effectively meet all office users' requirements. Some applications require high data rates; for example, real time graphic display information. Other applications require the lowest cost per connection; for example, data entry terminals. This fundamental tradeoff between performance and cost drives the evolution of a tiered network architecture for the office. A model based on tiered network architecture predicts that user workstations within a department will be clustered together, and that these clusters will be interconnected through a LAN Backbone network.

Today these two types of networks (cluster and LAN Backbone) can be realized by using available VLSI technology. Intel's 82586 LAN Coprocessor supports LAN Backbone technologies such as IEEE 802.3/Ethernet. The 82586 also supports the cluster networks by realizing 1 Mbps CSMA/CD networks. 1 Mbps networks are significantly cheaper than LAN Backbone networks because lower cost cabling and electronics can be used, and fewer repeaters are required between cable segments. In the future, PBXs will play an important role in this clustering tier as true two wire voice/data communication becomes a reality.

The Tiered Network Model

An office network can be thought of as consisting of three performance tiers. End users can optimize their network cost/performance ratio by building up networks with different performance attributes.

The Three Tier Network Model is shown in Figure 1. Tier 1, the highest performance tier, is referred to as the *Computer-to-Computer tier.* A network in this tier is characterized by a very high data rate, 50 to 100 Mbps. Solutions for this tier take the form of loops or rings and even fiber optics. An example of this type of network is Network Systems' Hyperchannel.

Tier 2, the *LAN Backbone,* is a high performance tier generally operating in the 10 Mbps data rate range and cover a distance sufficient for a single building. An example of this kind of network is the IEEE 802.3/Ethernet. This tier is the main highway over which information travels throughout a building connecting expensive peripherals (e.g. laser printers and file servers) to end users located in the clustered tier.

Tier 3, or the *Human Interface tier,* is characterized by the clustering of end user workstations. Networking capability in this tier exhibits the most cost sensitivity because the workstations themselves are numerous and low cost ($500 for a terminal to $3000 for a personal computer). Fortunately humans can tolerate display screen latencies of 0.5 to 1 second that lower bit rates provide. These lower bit rates enable low cost networks to be realized. The need for low cost is the reason why data rates in this tier are generally 1 Mbps or less. Examples of Tier 3 networks are personal computer networks such as Orvus Systems' Omninet, Orchid Technology's PCnet, Nestar's Plan Series and JEEE 802.3 Star LAN.

Voice/data PBXs will play an important role in Tier 3. Telecommunication suppliers have a big advantage in the office in that almost everyone has a phone on his desk. Today users take advantage of this installed network capability through modems. PBX manufacturers have already begun to make cluster products available in the form of voice/data PBXs. The data rates offered are 19.2 to 64 kbps in addition to voice, which is sufficient for terminal applications. These manufacturers are already reducing the terminal/station apparatus footprint size by offering teleterminal (combined terminal and phone) products.

A Three Tier Network Office/Commercial

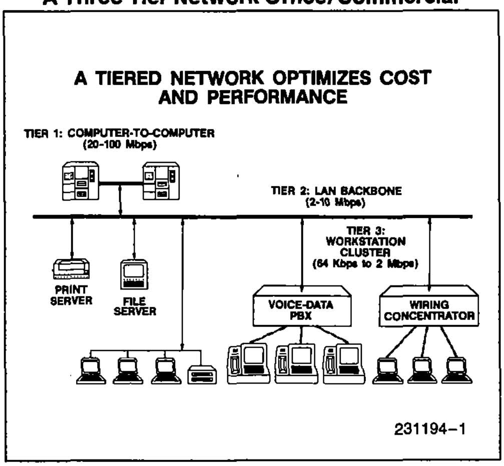

Figure 1. Three Tier Network Model

The tiered network model is analogous to a road system. Tier 1 is the 10 lane freeway in a major metropolitan area. This highway is responsible for moving very large volumes of traffic. This type of highway is very expensive to build, but the traffic volume warrants it. Tier 2 can be thought of as an Interstate Highway in which a large amount of traffic can be transported over long distances. Tier 3, or the Human Interface tier, can be thought of as the streets within a city which interconnect onto the interstate highway. In this scheme, no single user has a freeway butting up to his driveway; in a similar fashion no user is connected to a Tier 1 network. This tiered approach maximizes the performance of Tier 2, because most of the Tier 3 traffic stays within Tier 3; just as farm tractors primarily stay on dirt roads, not super highways.

Another way to view the model is to draw an analogy to microprocessors. To meet the requirements of diverse applications there are 4-bit, 8-bit, 16-bit and 32-bit processors available. Nobody questions that a 32-bit microprocessor is overkill for a microwave oven. In a similar fashion no single network can cost effectively solve the problems of each networking need. It is through this tiered approach that users achieve the best cost/performance ratio for moving vehicle traffic.

Applications and Tiers

This model can be mapped into application performance requirements found in the office. Figure 2 shows a graph of cost and performance for various applications. Experience has shown that end users are willing to pay no more than 10 to 15 percent of their system cost in order to obtain data communication capability; this percentage is an important assumption.

Application data rate requirements can be placed into three groups analogous to the three tiers of Figure 1. At the very high end is the computer-to-computer communication requirements, in which end users will spend $50k to $60k per connection.

At the high end is the CAD/CAM user requirements in which very expensive peripherals such as electrostatic plotters and disks need to be shared. The cost of an Ethernet connection, $1k to 1.5k, is very affordable at this tier.

At the lowest end is the terminal and personal computer requirements. This application space spans a wide spectrum of performance requirements. At the low end, data entry can tolerate very low data rates with not much performance degradation, and consequently is the most cost sensitive. Using modems as a benchmark, users are willing to pay upwards to $450 for a 1200 bps serial connection. At the higher end, resource sharing and graphic requirements for PCs require in the range of 1 Mbps. Popular personal computer LANs cost $500 to $1000 per connection (not including wiring cost).

Networking at Tier 3 provides an overall lower cost solution because the cost of the network is less than the cost of each user having his own peripheral. This observation is validated in that a major trend in the market place today is diskless workstations.

It is the wide range of personal computer and terminal data rate requirements that make the Tier 3 the most interesting. It is possible for a user to spend too much for performance he will not use. In fact, for personal computer networks, bit rate is not the major limitation, rather it is the restrictions of electro-mechanical peripherals such as Winchester disks and software overhead on the local CPU that cannot keep up with 1 Mbps *continuous* (as opposed to bursty) data rates.

Evolution Scenarios

Two scenarios have been developed to explain how a tiered network will be realized in the real world. Scenario 1, the local optimization scenario, assumes that departments within an organization will make their networking decision in isolation.

In this scenario the particular application requirements of a department are very well known. For example, an Engineering department has very high data rate requirements to support its CAD environment; whereas Sales has low data rate requirements for their order entry and order inquiry needs. Because the applications are well known, a decision can be made quickly on which network to purchase. Departmental budgets usually can cover the costs of these networks, so approval of a higher authority is not required. The result is that each department will develop its own cluster network (Tier 3).

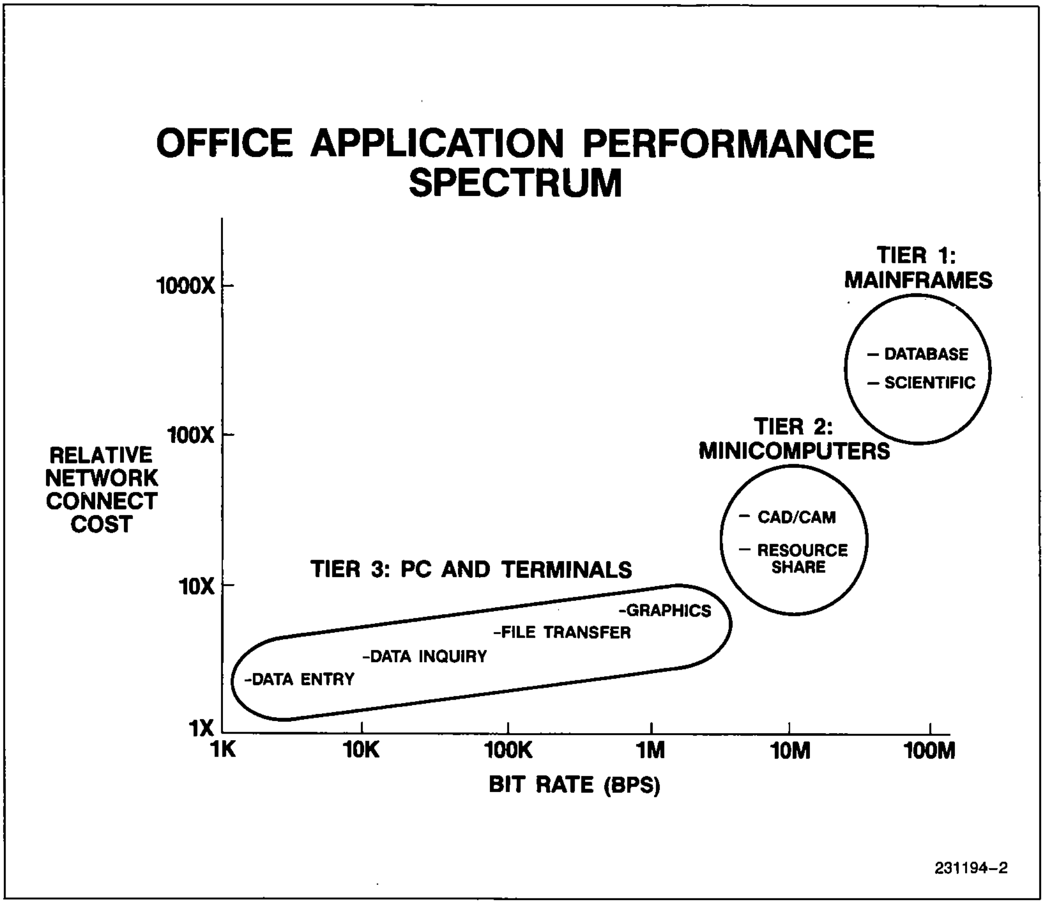

Figure 2. Application Performance Spectrum

However, over time many departments will develop their own cluster tier; each department will realize they have a need to interconnect among each other. For example, the Marketing department may have to access cost information from the Finance department as well as last month's order rate from Sales. When cluster-to-cluster communication requirements become important, the company will make a conscious decision to provide interconnect capability. This interconnect capability is realized through the LAN Backbone. A growing concern is whether gateways/bridges will exist. This concern leads to Scenario 2.

Scenario 2, the global optimization scenario, occurs when the users make a conscious decision to solve their networking requirements at one time. In this scenario, the decision is centralized because it impacts the entire operation or company. The advantage of this approach is built-in compability to interconnect the users. However, at this time the decision can be very difficult because the technology is not stable, and user requirements are not fully understood.

In this scenario the Tiered Network model predicts that clustering will occur as well. For example, it will not be cost effective for each user to connect onto an Ethernet cable ($1500 cost). Thus, each department will have a cluster optimized for its particular application interconnecting through a LAN Backbone.

To summarize, we can see that there is no single network that solves all user problems. Whether a user optimizes locally or globally, clustering is likely to occur. Each end user group will have a cluster that is optimized for its particular application requirements. It is through this clustering with interconnection through a LAN Backbone that end users will realize the most cost effective network.

VLSI and the LAN Backbone

The IEEE 802.3/Ethernet standard has gained wide acceptance by a number of system suppliers. IEEE 802.3's popularity has been driven primarily by its acceptance by major minicomputer manufacturers, the approved IEEE specification itself, and the availability of low cost VLSI controller chips. From a technical viewpoint, the IEEE 802.3 shares the benefits of Carrier Sense Multiple Access/Collision Detection, CSMA/CD, technology. These benefits are:

1. Proven technology. Ethernet has been in use since 1975 by Xerox. The technology is well-understood, and has resulted in the IEEE standard.
2. Performance. Elimination of the centralized (or hierarchical) control network communications results in greater efficiency and bandwidth utilization and shorter delay in getting the message to its destination.
3. Reliability. The CSMA/CD media access method enables the network to operate without central control or switching logic. If a station on the network malfunctions, it does not affect the ability of other stations to intercommunicate.
4. Easy expansion. The passive, distributed nature of a CSMA/CD network permits easy expansion. Stations can be added to the existing network without reinitialization of all the other stations. Such capability supports future growth requirements through simple expansion of the network.

Figure 3 shows the basic building blocks for an IEEE 802.3/Ethernet system and how it relates to the International Standards Organization (ISO) Open Systems Interconnect model for networking. Basic components consist of a coaxial cable for transmission media, a transceiver to transmit and receive signals that come over the media and detect collisions, a transceiver cable to connect the data terminal equipment to the transceiver which allows flexibility of the location of the terminal, and a controller board.

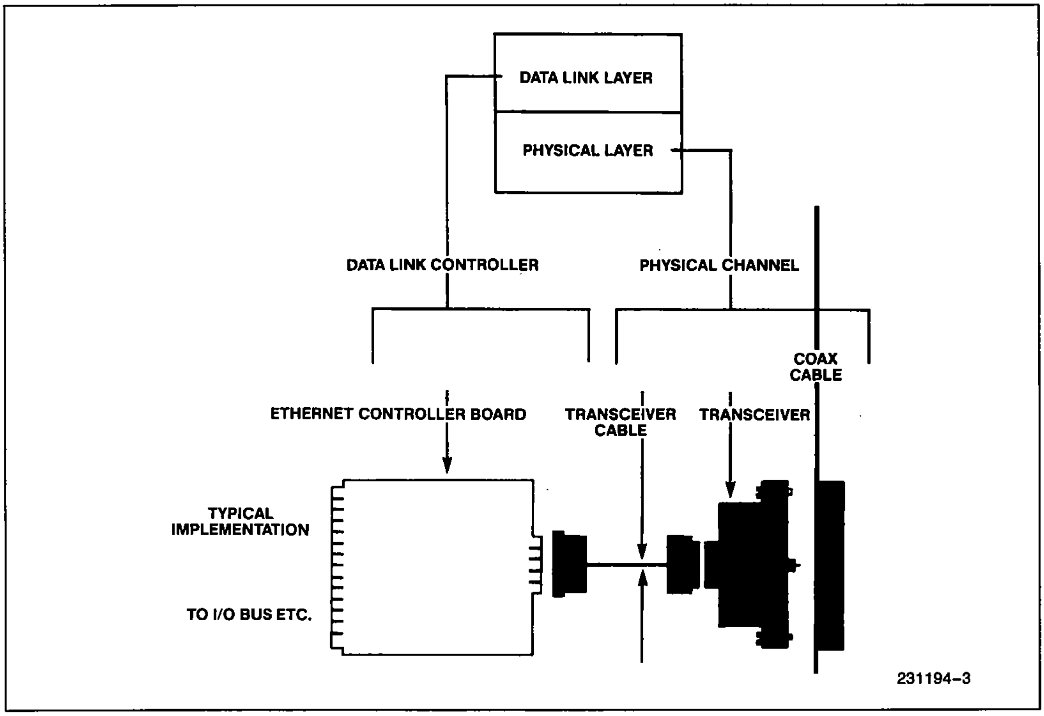

Figure 3. Ethernet Data Link and Physical Links

Today, Intel supplies VLSI for the controller board function. Intel's 82586 LAN Coprocessor performs the IEEE 802.3 data link functions *without any CPU involvement*:

* frame assembly/disassembly
* handling of source and destination addressing
* detection of physical channel transmission errors
* CSMA/CD network link management
  —collision detection
  —backoff and retransmission after a collision

In addition the 82586 supports the designer with diagnostic capability to make system design easier. For example DMA underrun and overrun errors, frames that are received in error, and number of deferrals are reported. Loopback capability is allowed to facilitate self diagnostics. These capabilities are performed without any involvement from the host CPU.

Intel's 82501, Ethernet Serial Interface, performs Manchester encoding and decoding of the data and timing information.

More details on operation and design support capabilities of the 82586 are included as an appendix to this paper.

VLSI For The Human Interface Tier

From a technology viewpoint, the Human Interface Tier is an interesting one. Traditional computer manufacturers and PBX manufacturers are providing solutions that leverage their traditional strengths. Computer manufacturers are providing solutions via LANs based on their data communications expertise. PBX manufacturers, on the other hand, are beginning to offer voice/data PBXs. While these are two competing technologies, both suppliers realize they do not have the complete solution. Minicomputer and PBX manufacturers have cooperated in developing the standard "Computer-to-PBX" interface. These technologies are discussed in greater detail below:

Cheapernet

Within the IEEE 802.3 committee is a subgroup defining a lower cost version of Ethernet called Cheapernet (also known as Thin Ethernet or Skinny Ethernet). *Cheapernet maintains Ethernet's 10 Mbps data rate,* but cost is reduced through a lower cost cabling scheme. Ethernet's yellow cable, cable tap box, and transceiver drop cable are replaced by low cost RG58 CATV coaxial cable. The Ethernet transceiver function is located within the terminal itself. The coax cable is attached directly to the terminal through a T-connector. Installation does not require a specialized craft person to install.

While this approach is lower in cost than Ethernet, it has two limitations. First, the segment length is restricted to 185 meters. For the office this distance limitation requires the use of repeaters that increase the cost and reduce system reliability. Second, the cable/terminal (ground) isolation scheme is the same as for Ethernet which requires D.C. isolation between the transceiver and the terminal (because of ground). This isolation scheme limits the potential cost reduction because it does not allow integrating the transceiver, encoder/decoder and controller functions into a single chip. Ethernet/Cheapernet require DC/DC converters to the transceiver.

1 Mbps CSMA/CD LAN

Today there are a number of personal computer network products that are unique to a single vendor. These networks lack the ability to electronically (physical link) interconnect, much less have compatible software link among other vendors. These networks are characterized by bit rates in the 1 Mbps area and are generally of the CSMA variety. In an effort to see a standard emerge in this area, Intel is working with AT&T, Wang, Tandem, Toshiba, and others to arrive at a 1 Mbps standard within the IEEE 802.3 committee.

1 Mbps networks offer a lower cost of connection than do 10 Mbps networks. First, cabling cost can be reduced by using low cost CATV coax, or twisted pair wire. Second, the length of cable segments can be much greater for 1 Mbps than in 10 Mbps technologies: going from less than 200 meters in Cheapernet, to 500 meters for Ethernet to over 1000 meters for 1 Mbps CSMA/CD. Longer cable segments mean few repeaters are needed on the network. Third, is that 1 Mbps networks allow VLSI interface costs to be reduced significantly. For 1 Mbps networks, it is possible with available technology to cost effectively integrate the controller function with the serial interface function and the transceivers into one chip. This level of integration is not achieveable in Ethernet/Cheapernet networks because the transceiver chip and serial interface chip are electrically isolated through transformers as mentioned above.

A concern is that 1 Mbps may not offer adequate performance for personal computer applications. The performance of 1 Mbps networks, such as Omninet and PCnet, is not limited by the serial bit rate, but rather electro-mechanical peripherals, particularly Winchester disk access time. Network performance (as measured by the time required for many users to down load a common file) can be significantly (3-4×) improved by using "RAM Disks" within the file server. RAM Disks are really extensions of the file server's local RAM memory that can hold commonly accessed files (such as a spread sheet program or BASIC language). Several personal computer network vendors already have these products available.

1 Mbps CSMA/CD networks can be cost effectively realized using the 82586 LAN Coprocessor from Intel. The 82586 is unique among present LAN controllers in that data rates and CSMA/CD network parameters (slot time, back-off priority, framing, etc.) are programmable. This programmability allows the 82586 to be used as a 1 Mbps controller. The advantage of this approach is that software developed for Ethernet workstations can be immediately transferred to 1 Mbps networks because the system interfaced to the 82586 remains the same. Available 1 Mbps Manchester encoder/decoders and a low cost discrete transceiver complete the 1 Mbps physical interface. Future cost reductions can be realized by integrating the controller and Manchester encoder/decoder and transceiver functions onto a single chip.

Voice/Data PBX

Many PBX manufacturers are touting voice/data capability. This capability usually takes the form of four wire systems in which voice and data are carried over separate twisted wire pairs. The data rates generally are 19.2 kbps or 56 kbps, depending on the asynchronous and synchronous nature of the data. Fourth generation PBXs, some using two wires, are beginning to enter the market now and will continue through the 1980's. Even these products have data rates ranging from 64 to 128 kbps, although 256 kbps for data is talked about. These data rates are adequate only for the Human Interface Tier.

Presently PBX manufacturers are focusing on the terminal application market as indicated by the numerous IBM 3270 interfaces offered. A 19.2 kbps data rate is more than adequate for data entry, data inquiry and editing applications. It is not clear whether this data rate is adequate for personal computers. Certainly for a personal computer working in an editing type environment, this performance is adequate. The PBX may not be adequate for applications that require heavy use of file access, file transfers and graphics.

Intel currently offers a family of components specifically designed to facilitate the design of voice/data PBXs. At the heart of the system is the 2952 Integrated Line Card Controller. This device supports 8 analog or digital subscribers simultaneously. It includes an interface to 2 PCM highways and 1 HDLC control highway. Analog subscribers interface to the 2952 through the 29C51 high feature CHMOS combo. The combo embodies both PCM codec and anti-alias filter functions on chip. In addition, integrated signaling test and line balancing are performed by the 29C51. Future products will allow PBX manufacturers to easily upgrade their 2952 based products to include true two wire voice/data subscribers.

Conclusion

There is no single local area network that meets every user's needs cost effectively. IEEE 802.3/Ethernet offers users a high performance Local Area Network suitable for a LAN Backbone, but it is too costly for personal computer and terminal networking. 1 Mbps networks and voice/data PBXs solve this problem. At present, Intel's 82586 LAN Coprocessor is the only VLSI chip that solves both Ethernet and 1 Mbps LAN requirements while simultaneously maintaining software compatibility from the system point of view. In the future it can be expected that LAN controllers optimized for 1 Mbps networks that include on chip encoder/decoder and transceiver functions will appear. Intel also offers a family of components to facilitate the realization of voice/data PBXs.

In the long run, office networks will be structured into department clusters that will be interconnected through a LAN Backbone or PBX. The ultimate choice will be related to application performance requirements.

References:

1. *LAN Components User's Manual* Intel Corp. Order Number: 230814-001
2. *Telecommunication Products Handbook* Intel Corp. Order Number: 230730-002

APPENDIX A
INTEL LAN SOLUTIONS

Intel offers a broad range of products to realize LANs. These products are in the form of components (82586 and 82501), boards (iSBC 186/51), and network software (iNA 960). See Figure A. A functional summary of components and software solutions is below:

The 82586 LAN Coprocessor

The 82586 is an intelligent peripheral that completely manages the processes of transmitting and receiving frames over a network. It offloads the host CPU of the tasks related to managing communication activities. More importantly, it does not depend on the host CPU for time critical functions (e.g. transmission and reception of frames) because it contains its own processor allowing it to be a coprocessor along with the host CPU.

The 82586 interfaces easily to available microprocessors. Systems requiring minimum component count can take advantage of its direct interface (no 'TTL glue') to Intel's 80188 (8-bit bus) and 80186 (16-bit bus) microprocessors.

The 82586 efficiently uses memory through data chaining. System memory is not wasted because short frame (75% of network traffic is less than 100 bytes) can be saved in minimal size buffers, while long frames are stored by successively chaining buffers together. It manages this chaining process without CPU intervention, thereby maintaining high system performance.

The 82586 facilitates network management by maintaining error tallies in system memory to count:

- Number of frames incorrectly received due to CRC errors
- Number of frames incorrectly received due to misaligned frames

The 82586 counts number of collisions that occurred while attempting to transmit a specific frame which is an indicator of traffic loading. It also monitors the transceiver's collision detection failure reporting mechanism.

The 82586 assists in developing and maintaining LAN systems by maintaining tallies that count the:

- Number of frames lost due to lack of receive buffers
- Number of frames lost due to DMA overrun while receiving frames

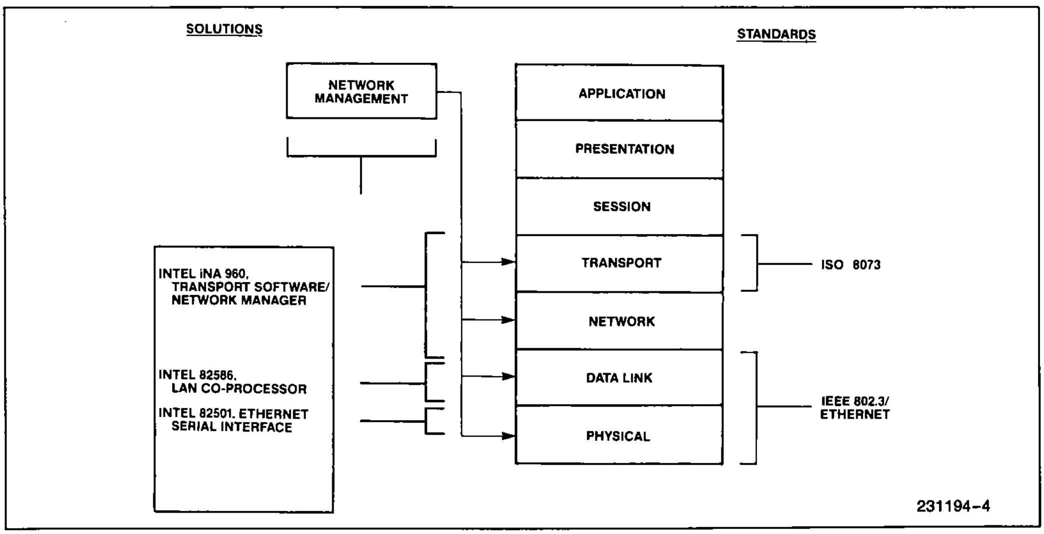

Figure A. Intel LAN Solution

The 82586 provides diagnostic capability via internal and external loopback service. Distance to cable breaks and shorts is provided by on-chip time domain reflectometry.

The 82586's network parameters are programmable so that LANs optimized to specific applications can be realized; for example: broadband networks, short topology networks that require higher throughput than IEEE 802.3 and low cost (1 Mbps) networks.

The 82501 Ethernet Serial Interface

The 82501 is designed to work directly with the 82586 in 10 Mbps LAN applications. The primary function of the 82501 is to perform Manchester encoding/decoding, provide 10 MHz transmit and receive clocks to the 82586, and to drive the transceiver cable. The 82501 provides for fault isolation via an internal loopback. Continuous transmission (babbling) is prevented by an on-chip watchdog timer.

iNA 960 Transport Software

iNA 960 is a general purpose Local Area Network software package that provides the user with guaranteed end to end message delivery. iNA 960 conforms to the International Standards Organization's 8073 specification including up to Class 4 transport layer services. iNA 960 also provides network management functions, and 82586 device drivers.

Transport Services

The iNA 960 transport layer implements two kinds of message delivery services: virtual circuits and datagram. Virtual circuits provide a reliable point-to-point message delivery service ensuring maximum data integrity and are fully compatible with the ISO 8073 Class 4 protocol. In addition to guaranteeing message integrity, iNA 960:

- Provides flow control (data rate matching between sender and receiver)
- Supports multiple simultaneous connections (process multiplexing)
- Handles variable length messages (independently of physical frame size)
- Supports expedited delivery (to transmit urgent data)

The datagram option provides 'best effort' delivery service for non-critical messages. The datagram service does not guarantee message integrity but requires less channel overhead than virtual circuits.

Network Management Services

The Network Management facility supports the users of the network in planning, operating and maintaining the network by providing network usage statistics, by allowing the monitoring of network functions and by detecting, isolating and correcting network faults.

The Network Management facility also supports up-line dumping and down-line loading of data bases or to boot systems without a local mass storage.

User Environment

In the iRMX (Intel's real time, multitasking operating system) environment, both the user programs and iNA 960 run under iRMX 86. The communications software is implemented as an iRMX 86 job requiring the nucleus only for most operations. The only exception is the boot server option, which also needs the Basic I/O System. iNA 960 will run in any iRMX environment including configurations based on the 80130 software on silicon component.

In those systems where iRMX 86 is not the primary operating system, or where off-loading the host of the communicatons tasks is necessary for performance reasons, the user may wish to dedicate a processor for communication purposes. iNA 960 can be configured to support such implementations by providing network services on an 8086, 8088, or 80186 microprocessor.

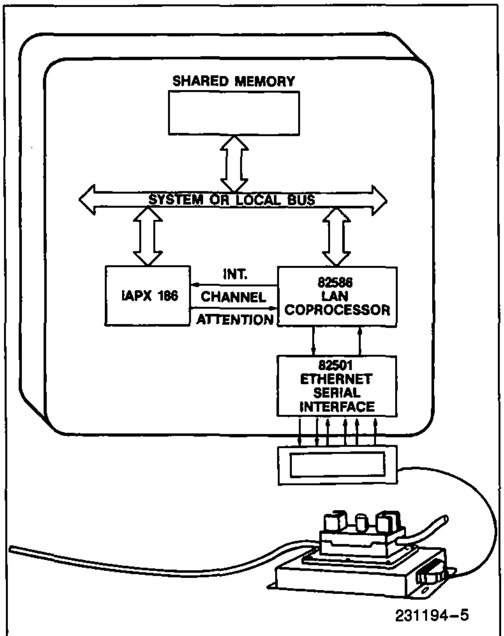

Figure B. Intel LAN Components

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